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In Memoriam: Herbert L. Needleman

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Herbert L. Needleman, MD, pediatrician, child psychiatrist, and hero for children's environmental health, died in Pittsburgh, Pennsylvania, on 18 July 2017.

Needleman was one of the world's foremost researchers on lead poisoning. He conducted seminal studies that illuminated with great clarity the enduring impacts of lead on children's health. He was a deeply moral man with a strong sense of social justice, a courageous and highly effective advocate who successfully translated his scientific findings into robust, evidence-based interventions that safeguarded the health of millions. He conducted much of this work in the face of powerful opposition.

Needleman's scientific work began when he was a young pediatrician at the Children's Hospital of Philadelphia in the late 1960s and early 1970s. He noted that children who had recovered from acute lead poisoning appeared frequently to have chronic residual neuropsychological impairment. He came to realize that lead poisoning was not an all-or-none phenomenon from which a child either died or recovered completely, as had previously been taught. Instead, he hypothesized that lower levels of exposure to lead that produce no clinically evident symptoms might nonetheless be associated with permanent neuropsychological deficits, albeit of lesser magnitude, a phenomenon now termed "subclinical toxicity."

Through his subsequent studies, Needleman documented that the loss of intelligence, the shortening of attention span, and the disruption of behavior that results from subclinical lead poisoning is permanent, untreatable, and irreversible. He therefore argued that the only rational approach to treatment of lead poisoning is to prevent exposure to lead.

In his first major epidemiologic study, Needleman conducted a cross-sectional evaluation of two groups of asymptomatic elementary school children in Boston. Needleman found a consistent mean decrement in intelligence of 6–7 IQ points in highly exposed children in comparison with their peers without elevated blood lead. The most severe deficits were seen in children with the greatest lead burdens (Needleman et al. 1979). Needleman also noticed that the highly exposed children were far less likely to have IQ scores >125 and much more likely to have IQ scores <70. They were also more likely to have behavioral problems, including an inability to focus, a shortened attention span, and impulsive hyper-aggressive behavior.

In a follow-up examination of the same two groups 11 y later, Needleman found that the association between lead exposure and impaired neuropsychological development had not gone away and now included a significantly higher frequency of school dropout, more learning disabilities, and poorer eye–hand coordination than their peers without elevated lead levels showed (Needleman et al. 1990). Even more troubling, the children who had been exposed to lead had a higher reported frequency of encounters with the police.

In his next major study, Needleman explored the impact on children's health of prenatal lead exposure. He and his team found that deficits in children's development were associated with blood lead levels at birth as low as 10–20 $\mu g/dL$ (Bellinger et al. 1986). Previously, toxicity had not been thought to occur at blood lead levels below 25–40 $\mu g/dL$.

Herbert L. Needleman, 1927–2017. Steve McCaw/Image Associates.

In his last major studies, Needleman examined the association between lead exposure and criminality. He compared the body lead burdens of incarcerated young men and nonincarcerated youth from the same communities. He found that the incarcerated young men had significantly higher lead burdens than their peers (Needleman et al. 1996). This finding strengthened Needleman's conclusion that strong links exist between lead exposure in early life and later increased risk for criminal behavior and added to the growing literature on the association between lead exposure and "violent crime" (Nevin 2000; Reyes 2007).

Needleman's work has had major consequences for public health and the economy. His findings provided the intellectual basis for decisions made by federal agencies to remove lead from gasoline and interior paint and to remediate lead contamination in many thousands of housing units across the United States. These interventions produced an estimated 94% reduction in blood lead levels in American children and also resulted in sharp decreases in incidence of lead poisoning (Annest et al. 1983). It has also been suggested that the nationwide reduction in lead exposure is at least partly responsible for a 5-point increase in mean IQ scores for children born in the United States since 1980, in comparison with those of children born in earlier decades (Grosse et al. 2002). Furthermore, the overall economic benefit of reducing lead exposures has been estimated at US$100–300 billion per year (Grosse et al. 2002).

Internationally, Needleman's findings provided the catalyst for nations around the world to remove lead from gasoline. Several countries, including Finland, Greece, India, and Thailand, have removed lead from gasoline, and children's blood lead levels in all those countries have fallen sharply as a result. The aggregate intelligence and economic productivity of entire societies have been enhanced as the direct result of Needleman's work (UNEP 2017).

In recognition of his scientific leadership and contribution to public health, Needleman was honored by the presentation of multiple awards, among them the Heinz Award for the Environment, the Charles A. Dana Award for Pioneering Achievement in Public Health, the Prince Mahidol Award for outstanding achievements in medicine and public health presented by the King of Thailand, the New York Academy of

Sciences Sarah L. Poiley Memorial Award, the National Wildlife Federation Conservation Achievement Award in Science, the University of Pittsburgh Chancellor's Distinguished Public Service Award, the Physicians Forum's Edward K. Barsky Award, the Society for Occupational and Environmental Health Vernon Houk Award, Muhlenberg College's Dr. John V. Shankweiler Prize, the Toxicology Landmarks Program Award from the Society of Toxicology, and the University of Pennsylvania's Distinguished Graduate Award.

Needleman's work, and especially his elaboration of the concept of subclinical toxicity, revolutionized scientific understanding of the neurodevelopmental impact not only of lead, but of a wide range of toxic chemicals. Needleman's work thus created a new paradigm for developmental neurotoxicology that took the field far beyond its earlier focus on acute, high-dose toxicity. Needleman demonstrated that harmful effects could occur at every level of exposure to a neurotoxicant, an observation that has now been replicated for many chemicals, among them methyl mercury, polychlorinated biphenyls, organophosphate pesticides, phthalates, and brominated flame retardants. Additionally, Needleman's work showed that exposure in early life to lead and other neurodevelopmental toxicants can produce lasting injury to the brain that, when widespread in a society, can have profound consequences for health, economic productivity, and political stability.

Herb Needleman was a warm, caring, and deeply ethical man. He was a generous and beloved mentor who nurtured and led a generation of younger researchers. He inspired us not only through the extraordinarily high quality of his science, but also through his deep thirst for social justice, his care for the oppressed, and his heroism in the face of adversity. Needleman's passing is a loss for America and for the world. He will be deeply missed.

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